EFFECTS OF FEEDING DIFFERENT MAGNESIUM LEVELS TO DRYLOT-FED GESTATING BEEF COWS

R. B. O'Kelley and J. P. Fontenot
Virginia Polytechnic Institute and State University, Blacksburg 24061

Summary

THREE experiments were conducted with eight gestating Angus cows to study the effects of feeding different magnesium levels at 145, 200 and 255 days gestation. Each trial consisted of a 5-day adjustment period and a 10-day experimental period. The average daily magnesium intake for the cows fed the basal ration was 3.4 grams. Supplemental magnesium was added at levels of 0, 4.1, 8.2 and 16.4 g per day. Blood and urine samples were taken at the end of the adjustment periods and on alternate days during the experimental periods.

At the three stages of gestation, increases in dietary magnesium significantly increased serum magnesium levels. Serum calcium and inorganic phosphorus levels were not consistently altered by the dietary magnesium level. Increases in dietary magnesium significantly increased urinary magnesium values per unit of creatinine. As calculated from regression equations obtained at each stage of gestation for the effect of dietary magnesium on serum magnesium, 8.5, 7.0, and 9.0 g of dietary magnesium would be required per day to maintain serum magnesium levels of 2.0 mg per 100 ml at 155, 200, and 255 days gestation, respectively.

Introduction

The occurrence of hypomagnesemic tetany, grass tetany or wheat poisoning in cows is well documented (Sjollema, 1932; Sims and Crookshank, 1956; Beardsley, McCormick and Southwell, 1963). In general, the disease affects less than 1% of the adult female population but the incidence may be considerably higher in individual herds. Hypomagnesemic tetany is most prevalent in lactating cows nursing calves less than 60 days of age (Crookshank and Sims, 1955) but has also been reported in gestating cows (Crookshank and Sims, 1955; Merchon and Custer, 1958; Beardsley et al., 1963). The magnesium requirement of gestating beef cows has not been extensively studied.

The objectives of the experiments reported here were to study the effects of different levels of dietary magnesium for beef cows during different stages of gestation.

Experimental Procedure

Three experiments were conducted with eight aged Angus cows (avg age, 13 years) at three stages of gestation. Experiments were conducted at approximately 145, 200 and 255 days post-breeding. The breeding dates were calculated from calving dates and were assumed to be 282 days before calving. The calculated breeding dates ranged from June 4 to July 7. Two consecutive trials were conducted during each experiment. Each trial consisted of a 5-day adjustment period and a 10-day experimental period.

Prior to the beginning of the first experiment, the cows were assigned to two groups according to their last known breeding date. For the first trial at each stage of gestation the cows within each group were randomly allotted to four rations containing different levels of magnesium. For the second trial, the cows within each group were reallocated to the four rations by incomplete randomization, the restriction being that no cow would receive the same ration for the two consecutive trials. Throughout the experiment, the cows were maintained in dry lot.

A low magnesium semi-purified basal ration (table 1) was fed during the three experiments. The ration was calculated to meet the nutritional requirements for gestating beef cows (Morrison, 1956) when fed at the rate
TABLE 1. COMPOSITION OF BASAL RATION *

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground corn cobs</td>
<td>40.4</td>
</tr>
<tr>
<td>Solka-floc b</td>
<td>34.0</td>
</tr>
<tr>
<td>Corn gluten meal, 61% crude protein</td>
<td>8.5</td>
</tr>
<tr>
<td>Cerelose b</td>
<td>8.3</td>
</tr>
<tr>
<td>Ground yellow shelled corn</td>
<td>7.5</td>
</tr>
<tr>
<td>Defluorinated phosphate</td>
<td>0.5</td>
</tr>
<tr>
<td>Trace mineralized salt</td>
<td>0.8</td>
</tr>
</tbody>
</table>

* Stabilized vitamin A was added at the level of 3,520 IU per kilogram.

The basal ration supplied an average of 3.4 g of magnesium per day. During the adjustment period, the cows were fed the basal ration supplemented with 21.7 g of supplemental magnesium as magnesium oxide, per head per day. The four rations fed during the 10-day experimental periods, consisted of the basal ration supplemented with 0, 4.1, 8.2 and 16.4 g magnesium per head per day, supplied by reagent grade magnesium oxide. The cows were placed in individual stalls for 2 hr. twice daily (8:00 am and 3:00 pm) and fed one-half of the respective rations. Feed samples were collected throughout each trial and composited for analyses. Blood samples were obtained via jugular puncture and urine samples were obtained via mechanical stimulation of the vulvar area at the end of each adjustment period and on alternate days during the experimental periods. Analytical procedures were as reported by O'Kelley and Fontenot (1969).

The data obtained on corresponding days of the two trials at each stage of gestation were combined and analyzed for differences among days and treatments by analysis of variance. Treatment differences were subjected to linear and multiple regression analyses.

**Results**

**Gestation, 145 Days.** As shown in figure 1, 2 days after the cows were fed the experimental rations, the blood serum magnesium levels for the four experimental rations were decreased below the initial values. All four experimental rations contained a lower level of dietary magnesium than the adjustment ration. The most pronounced decrease in serum magnesium occurred with cows fed the lowest level of magnesium. The values were decreased from an initial level of 2.38 mg per

![Figure 1. Effect of dietary magnesium level on blood serum magnesium—145 days gestation.](image-url)
100 ml to 1.59 mg per 100 ml by the sixth day of the experimental period (figure 1). The values for cows fed 3.8 or 7.9 g magnesium tended to remain constant after the sixth day of the experimental period. Values for cows fed 12.0 or 20.2 g magnesium did not change markedly after the first sampling day.

As shown in table 2, average serum magnesium values of 1.68, 1.99, 2.13 and 2.18 mg per 100 ml were obtained for the four levels of dietary magnesium, respectively. The serum magnesium values for the four levels of dietary magnesium at 145 days gestation followed a quadratic regression pattern, and the equation for the effect of grams of daily dietary magnesium (X) on serum magnesium (Y), expressed as mg/100 ml, was:

\[
Y = 1.34 + 0.1047X - 0.0032X^2
\]

\( (P<.01, R^2=0.47) \)

Serum calcium levels were not significantly altered by dietary magnesium level (table 2). Serum inorganic phosphorus levels decreased linearly (\( P<.01 \)) with increases in dietary magnesium. The values decreased from 6.60 mg per 100 ml for the cows fed 3.8 g magnesium to 5.68 mg per 100 ml for the cows fed 20.2 g magnesium.

Urinary magnesium excretion for the four levels of dietary magnesium ranged from 13.6 mg per 100 mg of creatinine for the lowest level of dietary magnesium to 30.3 mg per unit of creatinine for the highest level of dietary magnesium. The data followed a linear regression pattern (\( P<.01 \)). Average urinary calcium values obtained at the four levels of dietary magnesium showed a large degree of variation. Differences among days were significant, but differences among treatments were not.

**Gestation, 200 Days.** The average serum

<table>
<thead>
<tr>
<th>TABLE 2. EFFECT OF DIETARY MAGNESIUM LEVEL ON AVERAGE BLOOD SERUM MAGNESIUM, CALCIUM AND INORGANIC PHOSPHORUS AND URINARY MAGNESIUM AND CALCIUM AT 145-DAYS GESTATION*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Blood serum composition, mg/100 ml</td>
</tr>
<tr>
<td>Magnesium ( ^a )</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Inorganic phosphorus ( ^e )</td>
</tr>
<tr>
<td>Urinary concentration, mg/100 mg creatinine</td>
</tr>
<tr>
<td>Magnesium ( ^e )</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
</tbody>
</table>

* Average of samples taken on days 2, 4, 6, 8 and 10 for the two trials.

* Quadratic effect was significant (\( P<.01 \)).

* Linear effect was significant (\( P<.01 \)).

Values for cows fed 3.1 g magnesium per day dropped quite sharply from an initial value of 2.51 mg per 100 ml to a low of 1.65 mg per 100 ml on the eighth day of the experiment (figure 2). Decreases in serum magnesium were less severe for cows fed 7.2 or 11.3 g magnesium but tended to show a general decline during most of the experimental period. The initial serum magnesium value for cows fed the highest level of dietary magnesium was quite high in relation to the values obtained for the other three treatments and remained relatively high throughout the 10-day experimental period.

Increasing the level of dietary magnesium gave a linear increase in serum magnesium (table 3). The linear regression equation for the effect of grams dietary magnesium (X) on serum magnesium (Y), expressed as mg per 100 ml, was:

\[
Y = 1.68 + 0.0459X \quad (P<.01, R^2=0.57)
\]

Each 1 g increase in dietary magnesium, at the level used in this experiment, would increase the serum magnesium content 0.05 mg per 100 milliliters.

Serum calcium values were not significantly affected by level of dietary magnesium (table 3). Serum inorganic phosphorus values obtained at the four levels of dietary magnesium were significantly different and followed a cubic regression pattern. The values did not appear to be related to the magnesium content of the diet.

Increases in serum magnesium at the four levels of dietary magnesium were reflected in the urinary magnesium excretion per unit of creatinine. The values increased with level of dietary magnesium, and followed a linear regression pattern (\( P<.01 \)). Differences among days were also significant. Urinary calcium values increased with the first increase in dietary magnesium, then decreased with increases in dietary magnesium. The data were best represented by a cubic regression equation (\( P<.01 \)). Differences among days were significant.

**Gestation, 255 Days.** At the first sampling day, marked decreases in blood serum magnesium were evident for the cows fed 3.2, 7.3, or 11.4 g dietary magnesium per day (figure 3). Values for the cows fed 3.2 or 11.4 g magnesium per day continued to decrease until the sixth day and then progressively increased. Serum magnesium levels for cows fed 19.6 g dietary magnesium remained relatively constant.

Average serum magnesium values followed a linear regression pattern, \( Y = 1.61 + 0.0438X \)
MAGNESIUM FOR GESTATING BEEF COWS

2.9

DAILY DIETARY MAGNESIUM

○ 3.1g
○ 7.2g
○ 11.3g
○ 19.5g

Figure 2. Effect of dietary magnesium level on blood serum magnesium—200 days gestation.

(P<.01; R²=0.54) with (Y) representing the serum magnesium level (mg/100 ml) and (X), the level of dietary magnesium (g/day). Serum calcium and inorganic phosphorus values were similar for the four levels of dietary magnesium. (Table 4).

TABLE 3. EFFECT OF DIETARY MAGNESIUM LEVEL ON AVERAGE BLOOD SERUM MAGNESIUM, CALCIUM AND INORGANIC PHOSPHORUS AND URINARY MAGNESIUM AND CALCIUM AT 200-DAYS GESTATION a

<table>
<thead>
<tr>
<th>Dietary magnesium, g/day</th>
<th>3.1</th>
<th>7.2</th>
<th>11.3</th>
<th>19.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood serum composition, mg/100 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium b</td>
<td>1.86</td>
<td>1.96</td>
<td>2.20</td>
<td>2.58</td>
</tr>
<tr>
<td>Calcium</td>
<td>9.08</td>
<td>9.51</td>
<td>9.06</td>
<td>9.11</td>
</tr>
<tr>
<td>Inorganic phosphorus e</td>
<td>6.20</td>
<td>5.75</td>
<td>6.96</td>
<td>6.60</td>
</tr>
<tr>
<td>Urinary concentration, mg/100 mg creatinine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium b</td>
<td>18.86</td>
<td>27.86</td>
<td>32.32</td>
<td>44.06</td>
</tr>
<tr>
<td>Calcium d</td>
<td>17.82</td>
<td>33.52</td>
<td>11.18</td>
<td>6.13</td>
</tr>
</tbody>
</table>

a Average of samples taken on days 2, 4, 6, 8 and 10 for the two trials.
b Linear effect was significant (P<.01).
e Cubic effect was significant (P<.05).
d Cubic effect was significant (P<.01).

Urinary magnesium excretion per unit of creatinine significantly increased with each increased level of dietary magnesium (table 4). The increase in magnesium excretion was less at the highest level of dietary magnesium and the data were best represented by a quadratic regression pattern (P<.01). Differences in urinary calcium excretion were significant but could not be represented by a linear or multiple regression pattern.

Discussion

The four rations fed at 145, 200 and 255 days gestation contained lower levels of dietary magnesium than the adjustment rations. After 2 days on the experimental rations, generally, the cows on all four levels of dietary magnesium showed decreased serum magnesium levels. A similar decrease was noted by Rook (1961) and Rook, Campling and Johnson (1964) when dairy cows were placed on low-magnesium diets. At the three stages of gestation, the lowest serum magnesium levels
Figure 3. Effect of dietary magnesium level on blood serum magnesium—255 days gestation.

obtained for cows fed the lowest level of dietary magnesium were observed on the sixth or eighth day of the experimental period. Although further decreases occurred after the first sampling day for the higher level of dietary magnesium, the decreases were less pronounced. A similar trend was observed with lactating cows (O'Kelley and Fontenot, 1969).

Throughout the gestation period, increases in dietary magnesium were reflected in the concentration of urinary magnesium per unit of creatinine, indicating a greater total magnesium absorption with increases in dietary magnesium. Field, McCollum and Butler (1958), using sheep, found urinary magnesium to be proportional to the level of dietary magnesium. According to Rook, Balch and Line (1958) and L'Estrange and Axford (1966), magnesium absorbed in excess of the body requirement is excreted in the urine. Although serum magnesium values below the threshold level of 2.15 mg per 100 ml suggested by Rook et al. (1958) were frequently obtained during the three experiments, measurable amounts of magnesium were always present in the urine. Serum magnesium values below the threshold level of 1.50 mg per 100 ml suggested by Storry and Rook (1963) were not obtained. Urinary calcium values did not appear to be affected by the level of dietary magnesium.

Serum inorganic phosphorus values decreased linearly as the level of dietary magnesium increased at 145 days gestation. These results are consistent with the trend observed with cows during early lactation (O'Kelley and Fontenot, 1969). Crookshank and Sims (1955) found that serum inorganic phosphorus values tended to decrease with the development of hypomagnesemia. Fontenot et al.
(1965), in field studies, reported that the level of serum magnesium was not consistently related to serum inorganic phosphorus values. L'Estrange and Axford (1964) produced hypomagnesemia in lactating ewes by feeding a low-magnesium diet, but serum inorganic phosphorus values remained within the normal range. In the research reported here, at 200 days gestation, serum inorganic phosphorus values were significantly different between treatments, but the values did not appear to be related to the levels of dietary magnesium. At 255 days gestation, differences in serum inorganic phosphorus levels among cows fed the four levels of dietary magnesium were not significant.

Feed consumption was quite satisfactory at all levels of dietary magnesium throughout the gestation period. Refusals were not excessive and did not appear to be related to the level of dietary magnesium. The basal ration used in the three experiments contained an average of 3.4 g magnesium per day. Rook et al. (1964) observed a loss of appetite and large feed refusals when lactating dairy cows were fed a diet containing 3 g per day of magnesium, L'Estrange and Axford (1964) noted a loss of appetite in lactating ewes fed a low magnesium semi-purified diet. Possibly, the effects of magnesium deficiency on appetite in those studies were accentuated by lactation.

The observed and predicted values for serum magnesium were similar during the three gestation periods (figure 4). From the regression equation for the effect of dietary magnesium (X) on serum magnesium (Y) at 145, 200 and 255-days gestation, it was calculated that 8.5, 7.0, and 9.0 g of dietary magnesium per day would be required to maintain serum magnesium levels of 2.0 mg per 100 ml at the three respective stages of gestation. Based on a dry matter intake of 6.8 kg per day (N.R.C., 1970), 0.12, 0.10, and 0.13% dietary magnesium, dry basis, would be required at the three stages of gestation, respectively. The values are lower than those reported for lactating beef cows (O'Kelley and Fontenot, 1969). In that research 18 to 22 g magnesium were calculated to be needed to maintain serum magnesium levels of 2.0 mg per 100 milliliters. Ray (1942) reported the magnesium require-

![Figure 4](image-url)

Figure 4. Observed and predicted blood serum magnesium values at different stages of gestation as affected by dietary magnesium intake. The coefficients of determination (R²) were 0.47, 0.57 and 0.54 at 145, 200 and 255 days gestation, respectively. The standard errors of regression were: 145 days gestation, 0.0194 for X and 0.0008 for X²; 200 days gestation, 0.0045; 255 days gestation, 0.0045.
ment of dairy heifers was 30.8 mg per kilogram body weight or approximately 14 g per head for a 454 kg animal.

Literature Cited